2017-03

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http://hdl.handle.net/10026.1/9679

10.3390/su9030354
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Climate, Agroecology and Socio-Economic Determinants of Food Availability from Agriculture in Bangladesh, (1948–2008)

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Academic Editor: Manuel González de Molina
Received: 10 November 2016; Accepted: 24 February 2017; Published: 28 February 2017

Abstract: The paper examines the impacts of prices, resources, technology, education, public investments, climatic variables and agroecology on Food Availability (FA) from domestic agriculture in Bangladesh using a panel data of 17 regions covering a 61-year period (1948–2008) by utilising a dynamic agricultural supply response framework and Generalised Methods of Moments (GMM) estimator. Results revealed that FA has increased at the rate of 1.32% p.a. with significant regional variations. Significant regional differences exist with respect to climatic variables, resources, Green Revolution (GR) technology and education. Among the output prices, rise in the prices of rice, vegetables and pulses significantly increase FA whereas an increase in spice price significantly reduces FA. Among the input prices, a rise in labour wage significantly increases FA. FA increases significantly with an increase in GR technology expansion, as expected. Among the resources, increases in average farm size and labour stock per farm significantly increase FA, as expected. Among the climatic factors, a rise in annual minimum temperature significantly increases FA. FA is also significantly influenced by agroecological characteristics. FA is significantly higher in Karatoa floodplain and Atrai Basin but significantly lower in Ganges Tidal floodplain. Major disasters/events (i.e., the Liberation War of 1971 and 1988 flood) also significantly reduced FA, as expected. The key conclusion is that, over the past six decades, Food Availability in Bangladesh was significantly shaped by changes in climate, agrocology, output prices, resources and GR technology diffusion.

Keywords: food availability; climatic factors; agroecology; price and non-price factors; dynamic agricultural supply response; GMM estimator; panel data; Bangladesh

1. Introduction

Although it is assumed that the global food supply was sufficient to meet food needs of the world's population well into this century [1], unprecedented cereal shortages and hikes in food prices worldwide have made improving food security a top priority in the development agenda [2]. Food prices in the international market increased by 55% during 2004–2008 and then hiked again towards the end of 2011 and latter half of 2012 along with rises in energy and raw material prices [3]. Estimates of the world's undernourished people have fallen only by 216 million from 1.01 billion in 1990–1992 to 793 million in 2014–2015 [4]. However, the proportion of undernourished who are concentrated in three regions (i.e., Southern Asia, sub-Saharan Africa and Eastern Asia) has increased from 75.3% of total undernourished in 1990–1992 to 81.5% in 2014–2015 [4].

Asia, home to the largest number of undernourished people in the world, is facing serious challenges to its current and future food security [5]. The phenomenon of rising food prices with increasing food demand with inadequate supply coupled with declining investments in agricultural production and research and other infrastructure are raising serious concerns about the adequacy of food supplies in the region [6]. Additionally, it was predicted that climate change will have severe negative impacts on parts of Asia, with destructive storms, floods and droughts [5]. Climate change by 2020 is expected to thrust 50 million more people into poverty and hunger, which will further climb to 130 million by 2050 [7]. Msangi and Rosegrant [8] noted that South and East Asia will need to increase food production by about 70% and 30%, respectively, from year 2000 levels to keep up with demand by 2050. In addition, food prices will also increase by 20%, bringing an additional 158 million Asians into undernourishment [9].

Until the 1970s, food insecurity was linked to the failure or decline in food availability at the national level [10]. However, following Amartya Sen's claim that food insecurity is more of a demand concern, which affects the poor's access to food (i.e., an issue of entitlement) rather than a supply side concern affecting food availability at the national level, the focus of research shifted to the analysis of food insecurity at the household level [10]. Although there are several definitions of food security, the statement adopted at the 1996 World Food Summit is still the one most generally accepted: that all people, at all times have physical and economic access to sufficient, safe and nutritious food, to meet their dietary needs and food preferences for an active and healthy life [5]. The causes of food insecurity are multifaceted ranging from political instability, war and civil strife, macroeconomic imbalances and trade distortions to environmental degradation, poverty, population growth, gender inequality, inadequate education, and poor health [11]. However, all of these causes can be linked in some way to two basic root causes: (a) insufficient national food availability (a supply side issue); and (b) insufficient access to food by households and individuals (a demand side issue) [11]. Despite improved understanding of food security, many controversies on this issue have remained, including the relative importance of supply (food availability) versus demand (food access) variables in causing and solving food insecurity, among others [10].

In this study, we concentrate on investigating the supply side concerns of the food security nexus because it is currently being neglected in favour of examining demand side concerns largely concentrated at the household level at a given point in time. This is because food availability (FA) (in addition to food access and food utilisation) determines the food and nutrition security status at the individual and household levels [12]. Furthermore, FA at the micro level is strongly linked to the overall availability of food, which is determined by domestic food production, import of food and food aid, which in turn is influenced by domestic policies regarding food production [13].

Bangladesh, as one of the world's poorest and most populous countries, is also affected by high food prices [4], indicating its vulnerability in achieving food security. Although recent Millenium Development Goal (MDG) analysis identified Bangladesh as a nation that has attained some remarkable social and economic successes with respect to per capita income growth, reduction in population growth, maintenance of food production close to self-sufficiency level, and sustained trends of decline in income-poverty, but 31.5% of its population is still living below the poverty line according to the Bangladesh Household Income and Expenditure Survey 2010 [14]. However, this may not be viewed as unusual for a country of 143 million people trying to make a living on a small area of land (which works out roughly as less than 0.02 ha per person) and which is also frequently confronted by natural calamities and disasters [14]. Moreover, growth in population is expected to exert further pressure on key resources—such as water availability for agriculture—that in turn has a range of negative consequences for fisheries, soil salinity and the overall health of ecosystems [15], which is ultimately going to adversely affect the nation's food security.

A body of literature exists which has investigated either historical trends in food production and/or potential impacts of climate change on food production in Bangladesh [16–21]. Karmokar and Imon [21] analysed trends of rice production for the period 1971–2010 in Bangladesh and noted that rice production has increased at an estimated 1.02% p.a. Similarly, Alam and Islam [20] noted that per capita food availability (i.e., rice and wheat combined) has increased from 165.6 kg p.a. in 1991–1992 to 225.45 kg p.a. in 2009–2010 in Bangladesh, mainly owing to the expansion of GR technology. Karim et al. [19], using a bio-physical simulation model (ORYZA2000), predicted that average rice yield will reduce by 33% for 2046–2065 and 2081–2100 in three major rice-growing locations in Bangladesh and variable rainfall pattern and distribution will have negative impacts on rice yields by increasing demand for irrigation water by 14%. Sarker et al. [17,18] assessed the impact of climate change on mean yield and variability of rice for all three seasons (Aus, Aman and Boro) for the period 1972–2009 in Bangladesh and noted that the effects of changes in three major climate variables (i.e., minimum and maximum temperature and rainfall) vary among the crops. The effects of minimum and maximum temperatures are more prominent than rainfall. Also, results showed a higher level of variability for Aman rice (which is the main crop for the economy) as compared to Aus and Boro rice [17,18]. Amin et al. [16] investigated the impacts of climate change (i.e., changes in maximum temperature, minimum temperature, rainfall, humidity and sunshine) on the yield of three major rice crops of Aus, Aman and Boro seasons and wheat using national-level aggregate data for the period 1972–2010 in Bangladesh. They noted that the effects of changes for all climate variables were significant but varied in magnitude and direction across crops. Overall, maximum temperature adversely affected yield of all four crops, whereas rainfall severely affected Aman rice only [16].

It is clear from the aforementioned review that the attention of research on the historical trend of agricultural production and/or the impact of climate change on agriculture in Bangladesh remained confined to only rice crops, and sometimes wheat, mainly covering the period 1971–2010. Also, most of these studies concentrated on aggregate national-level data which is not capable of providing specific information on regional variabilities. Most importantly, none of these studies considered the impact of climatic factors as well as other socio-economic factors jointly on the broader question of food availability (which inherently includes supply of main rice and wheat crops) derived from the agricultural sector of Bangladesh disaggregated at a regional level while covering a much longer time horizon of 61 years (1948–2008). This longer time horizon is relatively more appropriate in capturing the effect of long-term changes in these variables.

Therefore, given this backdrop, the main objectives of this paper are to: (a) examine long-term trends in the capacity to supply food from Bangladesh's own agricultural resource base at the regional scale (17 regions) over a 61-year period (1948–2008); and (b) identify the impacts of output and input prices, socio-economic factors, climatic variables and agroecology on food availability (FA) in Bangladesh, a country most vulnerable to climate change, flooding and other vagaries of nature. This is because Bangladesh vigorously pursued a policy of achieving self-sufficiency in foodgrain production since the 1960s through the expansion of a rice-based Green Revolution (GR) technology including provision of High Yielding Varieties (HYVs) of rice seeds, inorganic fertilisers and irrigation and water control infrastructures. Therefore, it is important to identify which factors are positively influencing FA in the long run.

We use a proxy measure 'dietary energy supply' which is a standard measure of national food availability [11]. We express FA as 'dietary energy supply' from farm production measured in energy units, i.e., megajoules per ha of Gross Cropped Area (GCA). Although this 'calorie availability' or 'dietary energy supply' indicator—the oldest indicator of food security used by FAO—is being criticised for measurement errors, as well as its inability to make inter-country comparisons and its failure to account for nutritional inadequacy and shocks [22], this indicator can be meaningfully used for our purpose because we are interested in examining long-term trends in the capacity to produce food from the country's own agricultural resource base which is commensurate with the national policy of gaining self-sufficiency in food production, increasing food availability and sustaining food production in Bangladesh over time [23]. Also, steady growth in food availability could provide confidence in long-term sustainability of the agricultural sector of Bangladesh.

We undertake this task by utilising a dynamic agricultural supply response framework [24]. The contribution of our study to the existing literature on food supply are as follows. First, we extend the traditional supply response analysis of examining the impact of only prices to different impacts of prices, technology, resources, public investment, education, climatic variables and agroecology on food supply or FA. Second, we tackle the endogeneity issue which is common in conventional supply response analysis by using a dynamic Generalised Methods of Moment (GMM) approach suitable for panel data. And third, results from this study can be adapted to other developing countries facing similar food supply concerns.

The rest of the paper is structured as follows. Section 2 presents the analytical framework of the study, develops the empirical model, and describes the data and its construction procedures. Section 3 presents the results. Section 4 provides conclusion and draws policy implications.

2. Materials and Methods

2.1. The Theoretical Model

The traditional Nerlovian supply approach is the most popular form of supply side analysis because it facilitates examination of the speed and level of adjustments to optimal land area allocation and yield of crops. Also, this approach is based on price expectations and adjustments to area [24]. In this approach, farmers' decision-making process or behaviour of production is influenced by both price and non-price factors, where prices include output and input prices and the non-price factors include exogenous variables, technology shifters, rainfall, irrigation, investment, resources, education, etc. [24,25].

Models of supply response for any individual crop can be formulated in terms of area or yield response, but there is usually a delay in adjustments of area and yield due to availability of resources and other production conditions and hence adoption of a dynamic approach is crucial [24]. In general, supply response analysis is a two-stage process. In the first stage, the farmer decides on the allocation of crop area based on expected prices and in the second stage the farmer determines optimal yield based on price, inputs, resource availability and climatic conditions, given area allocated [24].

We begin by specifying model of area planted to a single crop as a function of crop area, own price of the crop and prices of its competing crops in the previous periods and other exogenous factors such as technology shifters, climatic variables, resources, investment, education and agroecology. Assuming there are N regions over T periods, the area of crop l in the ith region in period t is defined as [24]:

$$y_{lit} = \alpha_{l0} + \sum_{e=1}^{m} \alpha_{1e} y_{li,t-e} + \sum_{k=1}^{n} \sum_{j} \beta_{ijk} x_{lij,t-k} + \eta_{li} + u_{lit} \tag{1}$$

$$E(\eta_{li}) = E(u_{lli}) = E(\eta_{li} u_{lit}) = 0,\ i = 1, \ldots N; t = 1,\ \ldots\ T$$

where y is the crop area; x_is are independent variables, i.e., prices and exogenous factors. Prices include real prices of own crop as well as competing crops of period $t-k$, and exogenous factors include technological shifters. All variables are in natural logs, α and β are the parameters to be estimated. The error terms have two orthogonal components: the stochastic individual effect η_{li} and the idiosyncratic shock u_{lit}. Following Yu et al. [24], we assume that the lag lengths m and n are sufficient to ensure that u_{lit} is a stochastic error.

Similarly, the second stage yield response function for a single crop can be defined as:

$$q_{lit} = \alpha_{l0} + \sum_{e=1}^{m} \alpha_{1e} q_{li,t-e} + \sum_{k=1}^{n} \sum_{j} \beta_{ijk} x_{lij,t-k} + \eta_{li} + u_{lit} \tag{2}$$

$$E(\eta_{li}) = E(u_{lli}) = E(\eta_{li} u_{lit}) = 0,\ i = 1, \ldots N; t = 1,\ \ldots\ T$$

where q is the crop yield and the remaining variables were defined earlier.

We extend this dynamic yield response function of a single crop to aggregate yield of all food crops which is defined as food availability expressed in its energy equivalent form (i.e., dietary energy supply in megajoules per ha). In other words, the variable q is treated as FA per ha of gross copped area in this study.

2.2. Data

The annual time-series data disaggregated by 17 regions used for the analysis were constructed from various sources. The principal data on Bangladesh agricultural sector is taken from the special issue of Statistical Yearbook of Bangladesh which reports land area, production and yield of all major crops covering the period 1948–1972 [26]; various issues of the annual Statistical Yearbook of Bangladesh covering the period 1975 to 2011 [27–41]; agricultural databases covering the period 1948–1990 compiled and published by Hamid [42,43]; agricultural censuses of Bangladesh 1983/4, 1996 and 2008 [44–46] and Ahmad [47]; population censuses of Pakistan 1951 and 1961 [48,49] and Bangladesh 1974, 1981, 1991, 2001, and 2011 [50–54]; Bangladesh Water Development Board [55]; Bangladesh Meteorological Department; agricultural census of Pakistan 1960 [56]; Bangladesh Bank [57–61]; Quddus [62]; FAOSTAT [63]; Barker et al. [64]; Tripathi and Prasad [65] and Agricultural Statistics of India [66]. Please note that although Bangladesh now has 64 districts, most time-series are largely available at the greater district level—i.e., the system prevailing until 1981—and are here referred to as regions.

2.2.1. Dependent Variable: Food Availability

One of the principal objectives of Bangladeshi agricultural policy is to improve food availability [23]. We express FA as 'dietary energy supply' from agricultural production measured in energy units, i.e., megajoules per ha of gross cropped area at the regional level. Energy availability from food crops was determined using the standard caloric availability per 100 gm of individual crop weighted by its share of edible portion [23]. The information on calorie availability and the share of edible portion of each crop was taken from the Household Income and Expenditure Survey 2005 of Bangladesh [67].

The construction procedure is as follows. For example, first total production of all types of paddy for each year in each region was computed. These production figures were then converted to rice equivalent (i.e., edible portion) by multiplying with a factor of 0.66 (i.e., 1 kg of paddy yields 0.66 kg of rice). Then the total rice equivalent in kg for each year for each region is then multiplied by 3465 (i.e., 1 kg of rice contains 3465 calories of energy) to arrive at total rice energy in calories. Similar procedure was repeated for each individual crop for each region for each year using its specific edible portion and calorie content. Then the total energy equivalent of all food crops under consideration for each region for each year was then divided by the Gross Cropped Area of each region for each year to arrive at total food energy yield or FA in calories per ha which was then converted to FA in megajoule (MJ) per ha by dividing by 238.8458 (i.e., 1 MJ = 238.8458 calories).

2.2.2. Explanatory Variables: Prices, Socio-Economic Factors, Climatic Variables and Agroecology

A wide range of variables were incorporated in the econometric model. These are: prices of representative crop from each of the major crop groups (i.e., rice price, vegetable price, pulses price, oilseed price and spice price); input prices (i.e., fertiliser price and labour wage); education (i.e., literacy rate); resources and wealth (i.e., average farm size, labour stock per farm, animal power per farm); technology (i.e., GR technology and irrigation); government investment (i.e., R&D investment per farm and extension expenditure per farm), climatic variables (i.e., average minimum annual temperature and rainfall variability) and agroecology. The definition and construction details of these variables are relegated to the appendix (see Appendix A).

Apart from including prices in the model of supply response function, the justification for including other variables is as follows. Land is a scarce resource and a source of wealth in Bangladesh. Therefore, farm size is an important determinant of food production derived from farming. Also, larger farm areas can be allocated to a single crop or even more crops [68]. Hence, the average farm size (representing wealth and resource base) was incorporated to test its independent influence on FA.

Farmers in Bangladesh are also resource poor. In the absence of any reliable account of farm capital assets, livestock also serve as an important source of wealth and is an essential component in farming providing vital farm power services, which is in decline in recent years [69]. We include average number of livestock per farm (to represent wealth) to examine its influence on FA.

The GR technology was launched since the 1960s in order to attain self-sufficiency in foodgrain production in Bangladesh and is highly dependent on modern irrigation (i.e., particularly HYV *Boro* rice grown in dry winter season) and other modern inputs [70]. The stagnation in the expansion of HYV rice area is attributed largely to a lack of irrigation facilities [71,72], thereby limiting potential to improve food availability further. For example, only 44% of total rice area was irrigated in 2010 [41]. Therefore, a variable representing level and extent of GR technology was included in order to account for its independent influence on increasing FA.

Farmers' education is commonly used as an explanatory variable in technology adoption research [73]. Education serves as human capital stock and a proxy measure to access information as well as capacity to understand the technical aspects and profitability related to different crops which may influence crop choice decisions and hence affect FA. The average literacy rate was incorporated to reflect this.

The capacity to promote agricultural growth hinges largely on the effectiveness of the R&D activities in developing modern technologies. R&D activities in Bangladesh are chiefly concentrated on developing HYV rice varieties. A total of 131 improved varieties of various cereal and non-cereal crops have been developed so far and released by Bangladesh Agricultural Research Institute (BARI) [74]. Therefore, the total R&D expenditure variable was included to examine its independent effect on FA.

Agricultural extension is an important source of disseminating information related to farming, particularly in nations like Bangladesh where farmers have very limited access to information. For example, extension education was found to have significant influence on the adoption of land-improving technologies [75]. Therefore, the expenditure on extension per farm was incorporated to account for its independent influence on FA.

Bangladesh was earmarked as the country most vulnerable to climate change with large potential reduction in food production [16–21]. Yu et al. [24] specifically included rainfall and minimum temperature to investigate dynamic agricultural supply response in Henan Province of China over time with the assumption that crop yield is affected by minimum temperature and rainfall. Asada and Matsumoto [76] reported that the flood effect, which increased due to increased rainfall in the lower Ganges and the drought effect, which increased due to increased rainfall variation in the Brahmaputra Basin made rice production vulnerable to rainfall variation. Rainfall variability mainly affects the yield and cropping area of Kharif rice (dry season). A delay in the arrival of monsoon causes late transplanting of Aman rice (rice grown during the Kharif season) which causes low rice yield. Asada and Matsumoto [76] examined the effects of rainfall variation on Kharif rice in the Ganges-Brahmaputa Basin and reported that non-stationarity in the rainfall–rice production relationship was caused mainly by changes in rainfall patterns. Amin et al. [16] also reported that the yield and cropping area of Aman rice was significantly negatively affected by rainfall in Bangladesh. Variation of rainfall during the rainy season also affects rice production in Bangladesh. For example, Habiba et al. [77] reported that 1 mm increase in rainfall at vegetative, reproductive and ripening stages decreased Aman rice production by 0.036, 0.230 and 0.292 ton respectively. Therefore, two climatic variables, rainfall variability and average annual minimum temperature, were included to identify their independent influences on FA.

Agroecology is another important feature that either limits or opens up opportunities for farmers to choose their cropping portfolio, which remains largely ignored in the literature [78]. A total of 11 dummy variables representing agroecological characteristics (or AEZs) were incorporated in the model to identify their independent influence on FA, leaving the remaining 12th AEZ subsumed in the intercept/constant term.

Flood and drought occurs almost on an annual basis in selected regions of Bangladesh and are considered as a part of regular life cycle. However, Bangladesh also went through notable major disasters and/or events, which have caused damages to resources including costing human lives. We have incorporated dummy variables representing four major disasters and/or events that were believed to have the most adverse effect on agriculture and hence FA. These are the floods of 1988 and 1998 when large areas of Bangladesh were inundated for an extended period of time, a nine-month long War of Independence of Bangladesh in 1971 and Cyclone Sidr of 2007, which also resulted in a major flood.

2.3. The Econometric Model for Empirical Estimation

In order to identify the determinants of FA, we use the Dynamic Generalised Methods of Moment (GMM) estimator for panel data. We use this approach because a number of econometric problems may arise in a panel data framework. For instance: (a) the lagged dependent variable in Equation (2) is endogenous to the individual effect in the error term [24]; (b) a number of explanatory variables, such as the price variables, may be endogenous (i.e., past prices may have influence on FA), or correlated with the error term [24]; (c) the time-invariant characteristics (fixed effects) such as regions may be correlated with the explanatory variables. The fixed effects are contained in the error term in Equation (2), which consists of the unobserved region-specific effects and the observation-specific errors; and (d) the presence of the lagged dependent variable (i.e., FA of the previous year, $q_{li,t-1}$) gives rise to autocorrelation [79]. Allerano and Bond [80] proposed a method to estimate this dynamic panel data difference model using lagged endogenous and exogenous variables as instruments by applying GMM technique. Transforming Equation (2) into its first differences yields the following model [24]:

$$\Delta q_{lit} = \sum_{e=1}^{m} \alpha_{1e} \Delta q_{li,t-e} + \sum_{k=1}^{n} \sum_{j} \beta_{ijk} \Delta x_{lij,t-k} + \Delta u_{lit} \tag{3}$$

In order to address the presence of endogeniety and bias of the dynamic panel data, the GMM estimator makes full use of the conditional expectations of the product of the lagged dependent variables and all the moment equations of the model (for more details, please see Yu et al. [24] and Allerano and Bond [80]. The parameters of Equation (3) were estimated using a user-written program 'xtabond2' by Roodman [81] for STATA V10 software program [82]. The routine 'xtabond2' estimates the aforementioned Allerano-Bond Dynamic Panel GMM estimator [80] and is more flexible than the original Allerano-Bond GMM estimator using 'xtabond' command in STATA.

3. Results

3.1. Food Availability, Climate Change and Socio-Economic Factors

Table 1 presents mean level of FA in Bangladesh by regions in addition to other selected indicators including climate variables, resources and education. Overall, FA has increased substantially at the rate of 1.32% per year over a 61-year period in Bangladesh. The lowest rate of increase in FA was in Sylhet followed by Barisal and Chittagong. Sylhet is a hilly region famous for tea growing and forest products which are not captured in this dataset and do not add to FA computation. Barisal is a low-lying area where one crop of HYV rice is a major pattern and hence gain in FA is limited. Chittagong is a region with undulating topography. Therefore, low rate of increase in FA in these three regions are not surprising. Table 1 also confirms that the level of FA is highly variable across regions with significant differences. Table 1 also shows that significant differences exist with respect to climate variables (i.e., average annual maximum and minimum temperatures and total annual rainfall) and socio-economic factors including GR technology and education. The average annual minimum temperature increased at the rate of 0.05% p.a. ($p < 0.01$) and annual total rainfall increased at the rate of 0.26% p.a. ($p < 0.01$) during the period 1948–2008.

Table 1. Food availability, climate change variables and selected socio-economic factors by regions of Bangladesh (1948–2008).

Regions	Mean Level of FA ($MJ \cdot ha^{-1}$)	Average Annual Change in FA (%)	Mean Maximum Temperature (°C)	Mean Minimum Temperature (°C)	Mean Total Rainfall (mm)	Average Farm Size (ha)	Average Labour Stock per Farm (Persons)	Green Revolution Technology (%)	Literacy Rate (%)
Barisal	4958.66	0.44	30.43	21.33	2108.28	2.04	3.12	0.10	37.82
Bogra	7624.02	1.43	30.61	20.73	1701.87	2.36	2.42	0.30	27.90
Chittagong	7645.85	0.79	30.16	21.56	2849.80	1.45	2.75	0.47	37.19
Chittagong Hill Tracts	6733.48	1.30	30.52	21.34	2572.05	2.66	3.68	0.28	23.01
Comilla	6275.62	1.52	30.21	20.91	2275.41	1.32	2.96	0.28	30.71
Dhaka	7353.19	1.73	30.49	21.30	2182.30	1.81	3.92	0.20	41.00
Dinajpur	8291.38	1.40	30.31	19.92	1878.43	3.39	2.76	0.19	29.38
Faridpur	5864.10	1.28	30.17	21.00	1872.97	2.02	3.07	0.08	25.64
Jessore	6732.55	1.35	31.44	20.76	1584.79	2.60	2.66	0.22	30.23
Khulna	6043.32	1.08	31.16	21.80	1673.53	2.37	3.32	0.17	37.59
Kushtia	9807.36	1.21	30.24	21.60	2227.03	3.08	2.58	0.18	22.92
Mymensingh	6286.91	1.54	29.98	20.68	2125.02	2.15	3.83	0.25	23.55
Noakhali	5501.30	0.97	29.92	21.52	2999.80	1.48	2.45	0.26	33.19
Pabna	6776.84	1.92	30.89	20.38	1566.89	2.43	3.06	0.15	24.46
Rajshahi	9379.20	1.27	31.00	20.57	1540.39	2.87	3.16	0.22	27.21
Rangpur	6562.82	1.75	30.03	19.88	2248.90	2.31	3.49	0.22	24.72
Sylhet	9782.10	0.04	29.76	20.06	3813.80	2.57	3.56	0.21	29.28
Bangladesh	6918.75	1.32	30.43	20.90	2189.49	2.29	3.11	0.22	29.75
F-statistic$_{(16, 1036)}$	18.05 ***	–	47.21 ***	77.55 ***	69.53 ***	36.08 ***	3.11 ***	8.25 ***	17.19 ***

Note: *** significant at 1% level ($p < 0.01$).

3.2. Determinants of Food Availability

This section examines the determinants of FA at the regional level in Bangladesh. Table 2 presents the parameter estimates of Equation (3) using the Dynamic Panel GMM estimator. Prior to reporting the results, we discuss various hypothesis tests conducted to confirm validity of the model. We have specified all prices, climate change, farm size, and R&D and extension expenditure variables as endogenous and used the second lag of these endogenous variables as instruments using GMM estimator. The lower panel of Table 2 shows the results. Sargan's test has the null hypotheses of 'instruments as a group are exogenous'. Therefore, the higher the p-value of the Sargan statistic test is, the better [53]. Table 2 clearly shows that p-values of Sargan's test for overidentified restrictions and exogeneity of GMM instruments are large, as required. The Allerano–Bond test for autocorrelation has the null hypothesis of 'no autocorrelation' and is applied to differenced residuals. The AR(1) process for the first differences usually rejects the null hypothesis, but the important one is the AR(2) which will detect autocorrelation at the levels of the data [53]. Table 2 clearly shows that the AR(2) test cannot reject the null hypothesis of 'no autocorrelation'.

Table 2. Determinants of food availability in Bangladesh (1948–2008).

Variables	Dynamic GMM Estimator for Panel Data	
	Coefficients	***t*-Value**
Constant	−1.0450	−0.98
Lagged Food availability ($t-1$ year)	0.6768 ***	20.22
Crop prices		
Rice	0.0947 *	1.84
Vegetables	0.1861 ***	5.07
Spices	−0.1072 ***	−4.21
Pulses	0.0620 *	1.83
Oilseed	−0.0206	−0.57
Cash crop	−0.0137	−0.45
Input prices		
Urea fertiliser	−0.0391	−1.22
Labour wage	0.1119 ***	3.63
Education		
Literacy rate	0.0319	0.72
Resources		
Average farm size	0.1216 ***	2.80
Labour stock per farm	0.0878 ***	3.11
Animal power per farm	−0.0307	−0.99
Government investment		
R&D investment per farm	−0.0067	−0.81
Extension expenditure per farm	−0.0116	−0.97
Technology		
Green Revolution technology	0.0386 ***	7.87
Climatic variables		
Rainfall variability	0.0127	0.59
Average minimum annual temperature	0.7146 ***	2.88

Table 2. *Cont.*

Variables	Dynamic GMM Estimator for Panel Data	
	Coefficients	*t*-Value
Agroecology		
Old Himalayan Piedmont Plain and Tista Floodplain (HPTF)	0.0550	1.35
Karatoya Floodplain and Atrai Basin (KFAB)	0.0692 *	1.94
Brahmaputra-Jamuna Floodplain (BJF)	−0.0483	−1.02
High Ganges River Floodplain (HGRF)	0.0407	1.34
Low Ganges River Floodplain (LGRF)	0.0048	0.13
Ganges Tidal Floodplain (GTF)	−0.0716 *	−1.68
Sylhet Basin and Surma-Kushiyara Floodplain (SBSKF)	−0.0659	−1.49
Middle Meghna River Floodplain (MMRF)	−0.0136	−0.28
Lower Meghna River and Estuarine Floodplain (LMREF)	−0.0464	−1.08
Chittagong Coastal Plain and St. Martin's Coral Island (CCPSI)	0.0243	0.52
Greater Dhaka (DHAKA)	0.0098	0.21
Major disasters/events		
Flood of 1988	−0.3228 ***	−7.74
Flood of 1998	−0.0246	−0.61
Liberation War of 1971	−0.1776 ***	−3.36
Cyclone Sidr of 2007	−0.0445	−0.89
Model diagnostics		
$F_{(33,985)}$	167.53 ***	
Sargan's test for overidentified restrictions ($\chi^2_{500\ df}$)	510.30 ^{ns}	
Arellano-Bond test for AR(1) in first differences (*z*-statistic)	−7.36 ***	
Arellano-Bond test for AR(2) in first differences (*z*-statistic)	0.76 ^{ns}	
Difference-in-Sargan's tests of exogeneity of instrument subsets:		
GMM instruments for levels (null: H = exogenous) ($\chi^2_{223\ df}$)	161.28 ^{ns}	
IV instruments (null: H = exogenous) ($\chi^2_{15\ df}$)	23.74 ^{ns}	
Number of instruments	534	
Number of observations	1019	

Note: Instruments for first differences equation: Standard D. (lnliteracy lnlabourfarm lnanimfarm lngrtech hptf kfab bjf hgrf lgrf gtf sbskf mmrf lmref ccpsi dhakaeco flood88 flood98 famine liberty sidr07); GMM-type (Lag order 2 2, i.e., second order of the endogenous variables to be used as instruments (lnpaddy lnvege lnspices lnpulse lnoilseed lncash lnurea lnwage lnrain lnmintemp lnrdevfarm lnextfarm lnfarmsize)); *** significant at 1% level ($p < 0.01$); ** significant at 5% level ($p < 0.05$); * significant at 10% level ($p < 0.10$).

A series of hypothesis tests were conducted to justify use of our wide range of variables to explain FA (Table 3). Results of this exercise clearly show that the set of null-hypotheses that 'the coefficients on the output prices, input prices, climate variables, agroecology and major disasters/events are jointly zero' are strongly rejected at the 1% level of significance in all cases, thereby justifying inclusion of this wide range of variables to explain change in FA (Table 3).

Table 3. Test of hypotheses.

Model Specification Tests	F-Statistic	Decision
No influence of crop prices on FA H_O: Coefficients on the crop prices are jointly zero ($F_{6,\ 985\ df}$)	6.63 ***	H_O rejected (Crop prices significantly influence FA)
No influence of input prices on FA H_O: Coefficients on the input prices are jointly zero ($F_{4,\ 985\ df}$)	6.68 ***	H_O rejected (Input prices significantly influence FA)
No influence of climatic variables on FA H_O: Coefficients on the rainfall and temperature variables are jointly zero ($F_{2,\ 983\ df}$)	4.49 ***	H_O rejected (Climate has significant influence on FA)
No influence of agroecology on FA H_O: Coefficients on the agroecology variables are jointly zero ($F_{11,\ 985\ df}$)	3.62 ***	H_O rejected (Agroecological characteristics have significant influence on FA)
No influence of socio-economic factors on FA H_O: Coefficients on the socio-economic factors are jointly zero ($F_{7,\ 985\ df}$)	11.52 ***	H_O rejected (Socio-economic factors have significant influence on FA)
No influence of major disasters/events on FA H_O: Coefficients on the socio-economic factors are jointly zero ($F_{4,\ 985\ df}$)	17.54 ***	H_O rejected (Major disasters/events have significant influence on FA)

Note: *** significant at 1% level ($p < 0.01$).

Table 2 presents elasticities of FA with respect to the regressors. Overall, the fit is quite satisfactory as 42% of the coefficients on the regressors are significantly different from zero at the 10% level at least. Since the variables are specified in double log except dummy variables, the coefficients on the regressors can be read directly as elasticities with respect to FA. For the dummy variables, these coefficients represent discrete change from 0 to 1. Table 2 clearly shows that the previous year's FA has significant influence on current-year FA as expected. Among the crop prices, increase in the prices of rice, vegetables and pulses significantly increase FA, whereas an increase in the price of spices significantly reduces FA. It is well known that cereal, particularly rice, is the dominant crop in Bangladesh agriculture. Therefore, a rise in the price of rice provides incentive to the farmers to produce more rice which, being high in energy content, leads to an increase in FA. The elasticity value is estimated at 0.09 implying that a 1% increase in rice price will increase FA by 0.09%. Yu et al. [24] also noted that a rise in the price of grain leads the farmers in Henan Province of China to increase area allocated to maize. Similarly, a rise in the price of vegetables leads the farmers to produce more vegetables which in turn increases FA because of the high energy content of vegetables, particularly potatoes. The elasticity value is estimated at 0.19 implying that a 1% increase in vegetable price increases FA by 0.19%, which is substantial. Rahman [78] also noted that a rise in the relative price of vegetables leads to increase in agricultural land use diversity (i.e., moving away from crop monoculture) because vegetable production is relatively more profitable than rice. Similarly, a rise in pulses price leads farmers to produce more pulses which in turn increases FA because of high energy content in addition to being rich in protein. The elasticity value is lower and is estimated at 0.06. The negative influence of a rise in the price of spices is expected because the energy content of spices is very low and, therefore, switching to produce spices potentially reduces FA.

It is interesting to note that a rise in the price of urea fertiliser does not significantly reduce FA although it possesses the correct negative sign. This may be due to the fact that we have used real price of urea paid by the farmers which includes a high level of subsidy provided since the 1960s until 1992 when the input markets were liberalised, though it was reintroduced from 2002. Therefore, farmers' response to changes in the price of fertiliser is not prominent, implying that the use of urea fertiliser did not vary significantly with variation in its prices and as such did not have any significant adverse effect on FA. A rise in labour wage increases FA which seems to be at contrast with a priori expectation. The implication is that when labour cost increases with a rise in wage, farmers tend to switch to more profitable crops, such as vegetables; labour cost then increases which in turn leads to an increase in FA due to the crop's higher energy content. In fact, area, production and productivity of profitable crops such as potatoes and vegetables have been on the rise in Bangladesh, particularly during the period 1986–2006 [23]. Yu et al. [24] also noted that a rise in labour wage induces farmers in Henan Province of China to maximise their profit by moving labour from less profitable grain crops to more profitable crops, such as winter rapeseed or cotton, as labour cost increases.

Resources and technology exert significantly positive influence on FA. For example, increase in resources such as average farm size and labour stock per farm significantly increases FA. Larger farm size enables farmers to devote more land to field crops into either single or multiple crops at the farm level [68,69], which in turn increases FA. The impact of farm size is large with an elasticity value of 0.12. Similarly, increase in labour stock available at the farm level increases FA mainly through enabling farmers to operate more efficiently, thereby leading to increased productivity [83] and hence FA. The significant influence of GR technology in increasing FA is clear. It is an established fact that GR technology has raised cereal productivity substantially in Bangladesh [23,84].

Among the climate variables, a rise in the average annual minimum temperature significantly increases FA and the impact is very strong with an elasticity value of 0.74. The implication is that a rise in minimum temperature potentially limits the damaging impact of very low temperature on crops during the winter months, thereby increasing FA. Yu et al. [24] noted that higher minimum temperature in the previous season encourages farmers to allocate more land to winter crops, though yield gains are negative because crop cultivation was hindered by high temperature (not explicitly included in their model), thereby implying a potential negative impact of climate change. Sarker et al. [17,18] noted a significantly positive influence of a rise in minimum temperature on Boro rice yield (i.e., dry winter season rice) in Bangladesh although its influence on Aus (i.e., pre-monsoon season) and Aman (i.e., monsoon season) is negative. However, there is no influence of rainfall variability on FA. Sarker et al. [17] also noted no significant influence of rainfall on mean yield of three rice crops but reported mixed influence on mean yield variability instead in Bangladesh. Yu et al. [24] noted that rainfall has resulted in yield gain in winter wheat but loss in summer cotton crop in Henan Province, China.

FA is significantly influenced by agroecology. FA is significantly higher in Karatoa Floodplain and Atrai Basin (KFAB) but significantly lower in Ganges Tidal Floodplain (GTF). For example, the land type in KFAB consists of 19.7% of total land as high land (i.e., not prone to flooding) and 38.7% as medium high land (i.e., flooding depth 0.01–0.90 m) [85]. The fertility condition ranges from moderate to medium quality with soil type composed of silt loam and silt clay loam [62], which are highly suitable for crop production. As such, the share of HYV cereal area increased from only 18.7% during the 1980–1983 period to its highest level of 85.8% from 2000 to 2003 which not only led to an increase in cereal production but also led the region to experience a rise in per capita food grain production from 190 kg in 1981 to 310 kg in 2005, thus indicating an increase at a rate of 2.5% p.a. over the period [36]. All these factors contributed to significant increase in FA in this agroeological region. In contrast, although GTF has a very high proportion (94% of total land) of medium high land (i.e., flooding depth 0.01–0.90 m) [85], its cereal yield is relatively lower than other agroecological regions [62]. The share of HYV cereal area increased from 11.9% in the 1980–1983 period to only 26.3% from 2000 to 2003. Furthermore, the region did not experience any gain in per capita food grain production during the 1981 to 2005 period. The per capita food grain production remained stagnant at 170 kg over time. Also, the soil type is heavy silt clays and alkaline with medium to high fertility conditions. Rahman [78] also noted that agricultural land use diversity is significantly lower in GTF (Shannon index 0.41) as compared to KFAB (Shannon index 0.72). Sarker et al. [17] also found significant but mixed influence of regional dummies (used to represent climate zones) on the yield levels of Aus, Aman and Boro season rice crops in Bangladesh over time. In summary, it is clear that agroecological characteristics pose significant constraints and/or opportunities on FA.

As expected, the major disasters/events exerted significantly negative influence on FA. The negative impacts of the flood of 1988 and the War of Liberation in 1971 on FA were severe. During the flood of 1988, 89,970 sq km of area (i.e., 61% of the country) was inundated for a prolonged period of time [55]. Although the flood of 1998 inundated an even larger area of 100,250 sq km (i.e., 68% of the country), the duration of inundation was much shorter than the flood of 1988. The War of Liberation in 1971 lasted for a period of nine months, from 26 March to 16 December, which had significant negative impact on FA.

4. Conclusions

The aim of this study was to examine long-term trends in the capacity to produce food from Bangladesh's own agricultural resource base and to identify the determinants of food availability (FA) in the regions of Bangladesh covering a 61-year period (1948–2008). We adopted a dynamic agricultural supply response framework and implemented a dynamic Generalised Methods of Moments (GMM) estimator for panel data to estimate the econometric model. Results revealed that FA has actually increased at the rate of 1.32% per year, which is substantial because such a positive rate of increase, despite annual fluctuations, has been sustained over a prolonged period of 61 years. Significant differences exist amongst regions with respect to climate variables and key socio-economic indicators, which justifies the need to analyse FA at a disaggregated level, such as regions instead of at the national level.

A host of socio-economic, climatic and agroecological factors significantly influence FA. Among the price factors, it is evident that a rise in the prices of rice, vegetables and pulses significantly increases

FA, whereas an increase in the price of spices significantly reduces FA. Although fertiliser price has no effect on FA, an increase in labour wage significantly increases FA. Resources and technological advancement also significantly increase FA. FA increases significantly with increases in average farm size, average labour stock per farm and Green Revolution (GR) technology diffusion, consistent with expectation. Among the climatic factors, an increase in average annual minimum temperature significantly increases FA. Agroeoclogy also exerts significant but mixed influence on FA.

The key conclusion that can be derived from this research is that, over the past six decades, domestic food availability in Bangladesh was largely shaped by changes in climate, agroecology, output prices, resources at the farm level and GR technology diffusion. Among these factors, the relative contribution of climate was the highest in increasing FA over time followed by changes in the prices of vegetables, cereals and pulses and the availability of resources at the farm level. The widespread expansion of GR technology, launched in the 1960s, also contributed to an increase in FA, but the relative level of contribution was low. Policy makers and relevant stakeholders, therefore, should take into account the influence of these factors when designing food security policies and/or programs.

Acknowledgments: The database required for this project was created with funding support from Seale-Hayne Education Trust, UK (2011) and British Academy Small Research Grant, UK (2009). The author gratefully acknowledges the thoughtful and critical comments of the referees, which have improved the paper substantially. However, all caveats remain with the author.

Conflicts of Interest: The author declares no conflict of interest.

Appendix A

Table A1. Definition and Construction of Variables Used in the Model.

Variable Name	Definition and Construction Details
Food availability	To compute the food availability (FA) in megajoules per ha, edible energy equivalents of the quantity of total production under major eight crop groups is used. These are: (1) all seasons and varieties of rice (Aus, Aman, and Boro—the pre-monsoon, monsoon and dry winter seasons); (2) wheat (includes maize, barley, cheena, and other minor cereals); (3) sugarcane; (4) tubers (includes potatoes and sweet potatoes); (5) pulses (includes gram, mung, mashkalai, lentil, and khesari); (6) oilseeds (includes mustard and rapeseed); (7) vegetables (includes potatoes, arum, bean, cabbage, cauliflower, cucumber, jhinga, bitter gourd, brinjal, okra, patal, puisak, pumpkin, radish and water gourd); and (8) spices (chilli, garlic, ginger, onion and other minor spices) for each of the 17 regions (greater districts) for the period 1948–2008.
Labour stock per farm	Agricultural population (in thousands) for each region is used. Usable information on agricultural population appeared in agricultural censuses 1960, 1983/84, 1996 and 2008. Also, agricultural population by region was available for 1951 Population Census of East Pakistan. Although definitions of 'agricultural population' across periods may be likely to vary, this is a far closer measure of labour (both male and female) engaged in the sector rather than arbitrarily allocating all rural male population as labour input as done by previous studies. The data for the inter-census years were constructed using a standard linear trend extrapolation model. The series was then divided by number of farms available from census information which was constructed following the same procedure as above to create the time-series.
Animal power per farm	Number of draft animals (i.e., cattle and buffaloes) is estimated using linear trend extrapolation from actual counts available in the agricultural censuses of 1960, 1983/84, 1996 and 2008. The count for 1949 is taken from Ahmad [47]. The data for the inter-census years were constructed using a standard linear trend extrapolation model. The series was then divided by the number of farms derived above.

Table A1. *Cont.*

Variable Name	Definition and Construction Details
Crop output prices	Prices of major crop groups (defined above) were used. In order to avoid any potential endogeneity issues, use of national-level price is preferred because, in this case, prices faced by individual farmers or at the regional level are exogenous, as they are essentially price takers in the market. We have used prices of single or two dominant crops belonging to each major crop group, as prices of all individual crops covering such a long period of time were simply not available in any form and will be strongly correlated, thereby creating the multi-collinearity problem. Specifically, producer price of paddy representing all types of cereals, weighted average of garlic and onion prices representing all type spices, sugarcane price representing cash crop, lentil price representing all type of pulses, rapeseed price representing all types of oilseeds and weighted average price of green beans, cabbages, cauliflowers, broccoli, cucumbers, pumpkins, gourds, spinach and tomatoes representing all types of vegetables were utilised. These output prices were constructed as follows. Prices from 1966 onward were taken from FAOSTAT. Since prices of crops prior to 1966 were not available, the following strategy was used to derive those prices. Tripathi and Prasad [65] used a database of value of agricultural outputs (66 individual crops) in current and constant 1999/2000 prices for India for the period 1951–2000. Dividing the value of output of current price series with constant price series thus provided the deflator series. Then multiplying the harvest price of crops for West Bengal, India for the year 1999/2000 with the deflator series provided current prices of the selected crops in Indian rupees for the period 1951–1965 (the 1951 prices are repeated for 1948, 1949 and 1950 in absence of any additional information). These prices are then converted to equivalent Bangladeshi taka using appropriate exchange rate. After this, all price variables thus constructed are then converted into constant 1984/85 prices. Therefore, changes in the price series represent real changes in net prices of inflationary and other distortionary effects.
Fertiliser price	Producer prices of urea fertiliser (which is the major fertiliser used in Bangladesh) in current prices is available from FAOSTAT from 1961–2002. Prices from 2003–2008 was used from Kazal et al. [86]. Prices for missing years from 1948–1960 was replaced with price of current price of urea fertiliser of 1961. All fertiliser prices thus constructed are then converted into constant 1984/85 prices in order to reflect real changes in its price.
Labour wage	Agricultural labour wage information was taken from Barker et al. [64] and Statistical Yearbook of Bangladesh [27–41]. The wages at current market prices are then converted into constant 1984/85 prices to reflect real changes in labour wage.
Green Revolution technology	Bangladesh vigorously pursued a rice-based GR technology since the 1960s followed by expansion of modern varieties of wheat and maize since the late 1980s. To capture the role of GR technology on FA we used the product of the proportion of Gross Cropped Area (GCA) under modern varieties of rice and wheat and the proportion of irrigated area in GCA. We did this because these two variables are strongly correlated (r = 0.98, p < 0.01). Therefore, in order to break the correlation of these two important variables (i.e., area under modern rice and wheat varieties and area under irrigation), we applied a multiplicative term, i.e., HYV area × Irrigation area to capture the total effect of GR technology on FA. The total area (in acres or hectares) under modern varieties of rice and wheat and area under irrigation are available in various Yearbooks of Statistics of Bangladesh and is easy to compute.
Average farm size	Average farm size (ha per farm) is taken from Census of Pakistan 1951 and agricultural censuses of 1960, 1983/84, 1996 and 2008. The data for the inter-census years were constructed using a standard linear trend extrapolation model.
Average literacy rate	Average literacy rate of population aged 7 years and above is taken from Census of Pakistan 1951 and 1961 and Bangladesh Population censuses of 1974, 1981, 1991, 2001 and 2011. The data for the inter-census years were constructed using a standard linear trend extrapolation model.

Table A1. *Cont.*

Variable Name	Definition and Construction Details
R&D expenditure per farm	Research and Development (R&D) expenditure data is converted to a series involving a time-lag in order to take account of the time required for the technology generated by the research system to reach the farmers for adoption. In order to take the lag into account, the weighted sum of research expenditures over a period of 14 years is used. The research variable is constructed as $\Sigma W_{t-i}R_{t-i}$, where W_i is a weight and R_{t-i} is research investment in year *t-i* measured at constant 1984–1985 prices. The weight for the current year research expenditure is zero, for a one-year lag the weight is 0.2, while for a two-year lag it is 0.4, and so on (for details, see Dey and Evenson [87]). The series was then divided by the number of farms.
Extension Expenditure per farm	Total extension expenditure incurred by the MoA and/or the Department of Agricultural Extension (in million taka) at constant 1984/85 prices is used. Data prior to 1972 were collected from Pakistan Planning Commission reports and few missing years were interpolated using a standard linear trend extrapolation model. The series was then divided by the number of farms.
Rainfall variability	Total rainfall measured in mm for each region per month from a list of rainfall recording stations is available from 1948 onward (from Bangladesh Meteorological Department). The regional allocation of this rainfall information is made depending on the location of the rainfall station. Then rainfall variability is computed as standard deviation of monthly rainfall of each region for each year.
Average minimum temperature	Monthly maximum and minimum temperature is also available for each region from 1948 onward (from Bangladesh Meteorological Department). The average minimum temperature is computed from this information.
Agroecology	UNDP-FAO [88] conducted a major analysis to identify agroecological zones (AEZs) of Bangladesh which are based on mainly land types, soil types, fertility conditions, temperature and rainfall regimes. A total of 30 AEZs were identified which do not commensurate with administrative boundaries. Quddus [62] reclassified these 30 AEZs into 12 AEZs by combining more than one original AEZ so that the new classification is roughly commensurate with the administrative boundaries (i.e., 64 new districts which belongs to 17 greater districts or regions) for which secondary data are available (for details, see Table 1 in Quddus, 2009). We have created a set of 12 dummy variables representing these new 12 AEZs and allocated them to 17 regions as appropriate.
Major disasters/ events	Dummy variables for four major disasters or events were added to account for their individual effects on FA. These are the Liberation Was of 1971, flood of 1988, flood of 1998 and Cyclone Sidr of 2007.

Note: Adapted and modified from Appendix 1 of Rahman [78].

Table A2. Correlation matrix of the explanatory variables used in the econometric model.

	Prpaddy	Pvege	Pspice	Plentils	Prapeseed	Psugar	Ureapric
prpaddy	1						
pvege	0.0129	1					
pspice	−0.4774 *	0.1586 *	1				
plentil	−0.6039 *	0.0643 *	0.5467 *	1			
prapeseed	0.5022 *	−0.1512 *	−0.1993 *	−0.2906 *	1		
psugar	0.5940 *	0.4078 *	−0.4433 *	−0.5565 *	0.2209 *	1	
ureapric	0.3600 *	−0.2853 *	−0.1027 *	−0.4201 *	0.4333 *	0.0891 *	1
wage	−0.2412 *	−0.0355	0.1840 *	0.3780 *	−0.0568	−0.2190 *	−0.3141 *
rainfall	−0.1424 *	0.0845 *	0.1590 *	0.0923 *	−0.0945 *	−0.0359	−0.0087
mintemp	−0.1595 *	−0.0464	0.1663 *	0.2083 *	−0.1338 *	−0.1644 *	−0.1509 *
literacy	−0.7055 *	0.0025	0.4422 *	0.7318 *	−0.4372 *	−0.5801 *	−0.5121 *
farmsize	0.6003 *	0.0643 *	−0.4171 *	−0.5468 *	0.2859 *	0.5334 *	0.2291 *
labourfarm	−0.4777 *	−0.0449	0.2344 *	0.2612 *	−0.3878 *	−0.3153 *	−0.2512 *
animfarm	−0.4126 *	−0.0009	0.2242 *	0.1761 *	−0.2340 *	−0.2415 *	−0.1205 *
rdevfarm	−0.5748 *	−0.0025	0.3553 *	0.4570 *	−0.4111 *	−0.4309 *	−0.3310 *
extfarm	−0.5583 *	0.0121	0.2326 *	0.4459 *	−0.4063 *	−0.3657 *	−0.4876 *
grtech	−0.6114 *	0.0815 *	0.4029 *	0.7208 *	−0.4044 *	−0.4835 *	−0.5411 *

Table A2. *Cont.*

	Prpaddy	Pvege	Pspice	Plentils	Prapeseed	Psugar	Ureapric
	Wage	**Rainfall**	**Mintemp**	**Literacy**	**Farmsize**	**Labour~m**	**Animfarm**
wage	1						
rainfall	−0.0040	1					
mintemp	0.1370 *	0.0933 *	1				
literacy	0.4142 *	0.1109 *	0.3513 *	1			
farmsize	−0.1634 *	−0.2540 *	−0.3427 *	−0.6780 *	1		
labourfarm	−0.1654 *	0.042	0.01	0.3813 *	−0.3418 *	1	
animfarm	−0.2120 *	−0.0424	−0.1694 *	0.2592 *	−0.1450 *	0.8533 *	1
rdevfarm	0.0505	0.1049 *	0.1583 *	0.4608 *	−0.3972 *	0.6373 *	0.5292 *
extfarm	0.2079 *	0.0928 *	0.1632 *	0.5318 *	−0.3419 *	0.5922 *	0.4581 *
grtech	0.4004 *	0.0824 *	0.1539 *	0.6677 *	−0.5362 *	0.2408 *	0.1615 *
	Rdevfarm	**Extfarm**	**Grtech**				
rdevfarm	1						
extfarm	0.8099 *	1					
grtech	0.3800 *	0.4223 *	1				

Note: * = significant at 5% level ($p < 0.05$).

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